National Bureau of Standards

February 1957
Volume 41
Number 2

Technical News Bulletin

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MAR 7 1957
DETROIT

Maximum Permissible Radiation Exposures to Man

A Preliminary Statement of the National Committee on Radiation Protection and Measurement

The accompanying Preliminary Statement of the National Committee on Radiation Protection and Measurement (NCRP) presents in brief form the essential changes introduced by its new recommendations on the safe limits of radiation exposure. In making the new recommendations, the Committee reviewed its past recommendations in the light of increased knowledge about the long-range effects of radiation exposure on the genetic makeup and life-expectancy of man.

The NCRP, an advisory group of experts in various phases of the radiation field, is sponsored by the National Bureau of Standards. The Committee is made up of representatives from the following organizations: American College of Radiology, American Dental Association, American Industrial Hygiene Association, American Medical Association, American Radium Society, American Roentgen Ray Society, International Association of Government Labor Officials, National Bureau of Standards, National Electrical Manufacturers Association, Radiological Society of North America, U. S. Air Force, U. S. Army, U. S. Atomic Energy Commission, U. S. Navy, and U. S. Public Health Service. The reports of the Committee are published in the NBS Handbook series.

Because the new recommendations of the NCRP will affect material contained in many of its handbooks, revisions of the latter will be undertaken at an early date. Until these revisions are completed and ready for publication, an effort will be made to prepare for each handbook a simplified statement of the changes needed to comply with the new recommendations. These summary statements will be released to the technical journals for publication as they are completed, and will be used with the handbooks now in stock. The full and detailed changes will be incorporated in the revised editions of the handbooks.

Since the publication of NBS Handbook 59 on Permissible Dose from External Sources of Ionizing Radiation, the National Committee on Radiation Protection and Measurement (NCRP) has continued the study and review of its recommendations,[1] particularly with respect to genetic effects and the possible shortening of average life expectancy due to radiation exposure of a larger fraction of the population. The NCRP proposals resulting from these studies had an important influence on the decisions reached by the International Commission on Radiological Protection (ICRP) in Geneva in April 1956,[2] which resulted in a general

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lowering of the maximum permissible accumulated dose (MPD) for occupational radiation exposures, as well as for exposures of the population as a whole. These changes are in accord with the informal agreements reached by the ICRP in Stockholm in 1952.

The NCRP has now agreed upon the formulation of revised recommendations on maximum permissible doses which integrate the national and international views for practical application. The Committee is pleased to note that the findings of the ICRP are reinforced by the important information and data provided in the subsequent reports of the National Academy of Sciences and the British Medical Research Council.

The changes in the accumulated MPD are not the results of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has also been given to the probability of a large future increase in radiation uses. In spite of the trends, it is believed that the risk involved in delaying the activation of these recommendations is very small, if not negligible. Conditions in existing installations should be modified to meet the new recommendations as soon as practicable, and the new MPD limits should be used in the design and planning of future apparatus and installations. Because of the impact of these changes and the time required to modify existing equipment and installations, it is recommended on the basis of present knowledge that a conversion period of not more than 5 years be adopted, within which time all necessary modifications should be completed.

Definitions

For the purposes of this preliminary statement, the following tentative definitions are given:

Controlled Area. A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of a radiation safety officer. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Workload. The output of a radiation machine or a radioactive source integrated over a suitable time and expressed in appropriate units.

Occupancy Factor. The factor by which the workload should be multiplied to correct for the degree or type of occupancy of the area in question.

RBE Dose. RBE stands for relative biological effectiveness. An RBE dose is the dose measured in rems. (This is discussed in the forthcoming report of the International Commission on Radiological Units and Protection.)

MPD Recommendations for Occupational Conditions (Controlled Areas)

1. *Accumulated Dose.* The maximum permissible accumulated dose, in rems, at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems. Thus the accumulated MPD = 5 (N − 18) rems where N is the age and greater than 18. This applies to all critical organs except the skin, for which the value is double.

2. *Weekly Dose.* The previous permissible weekly whole-body dose of 0.3 rem, and the 13-week dose of 3 rems when the weekly limit is exceeded, are still considered to be the weekly MPD, with the above restriction for accumulated dose.

3. *Emergency Dose.* An accidental or emergency dose of 25 rems to the whole body, occurring only once in the lifetime of the person, shall be assumed to have no effect on the radiation tolerance status of that person. (See National Bureau of Standards Handbook 59.)

4. *Medical Dose.* Radiation exposures resulting from necessary medical and dental procedures shall be assumed to have no effect on the radiation tolerance status of the person concerned.

MPD Recommendations for the Whole Population

5. The maximum permissible dose to the gonads for the population of the United States as a whole from all sources of radiation, including medical and other man-made sources, and background, shall not exceed 14 million rems per million of population over the period from conception up to age 30, and one-third that amount in each decade thereafter. Averaging should be done for the population group in which cross-breeding may be expected.

Recommendations for Internal Emitters

6. In controlled areas, the permissible radiation levels for internal emitters will conform to the general principles outlined above. Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values heretofore specified for radiation workers. Where single organs other than the gonads are regarded as the critical organ, the present maximum permissible concentrations will continue. For individuals outside of controlled areas, the maximum permissible concentrations should be one-tenth of those for occupational exposures. (Other changes in the maxi-

mum permissible concentrations for radionuclides may be introduced because of additional information developed since the publication of National Bureau of Standards Handbook 52.)

Discussion of Revised Recommendations

7. The MPD for occupational exposure is based on the absence of detectable injury to the individual. It remains at its present level of 0.3 rem/week for the whole body. Where the dose in any week exceeds this value, a dose of 3 rems in 13 weeks may be accepted. The 13-week period may start at the beginning of the calendar quarter or the beginning of the week during which the permissible weekly dose was exceeded.

8. The rules given in Handbook 59 will be continued for operational and administrative purposes, but some of the rules will be modified by provisions related to an average yearly limitation of occupational exposure to external sources of ionizing radiation of 5 rems to the blood-forming organs, gonads, and lenses of the eyes, and of 10 rems to the skin. The use of "5 rems" in the statement of the revised rules is for the purpose of design and administration. The critical limitation will be that defined for the total accumulated dose in paragraph 1 above.

9. If a person's occupational exposure is documented or otherwise known with reasonable certainty, he may be permitted to use his reserve exposure in accordance with paragraphs 1 and 2 above. In all other cases, he shall be assumed to have received his maximum accumulated dose as indicated in paragraph 1 above.

10. It is considered that with the current and proposed low levels of occupational exposure, it is presently not necessary to make special allowance for medical exposure in conjunction with occupational exposure. This consideration may later become important. The effects of medical exposures have long been considered by this Committee to be the responsibility of the attending physician; it is his responsibility to evaluate medical radiation exposure in relation to the health of the individual. (See National Bureau of Standards Handbook 59.)

11. In the determination of the population dose in the vicinity of radiation sources, proper consideration should be given to occupancy factor and to workload. The exposure of individuals outside of controlled areas may be integrated over periods up to one year.

12. While at the moment it is not feasible to determine the average exposure for the population with any reasonable accuracy, the adoption of some figure is necessary for planning purposes. For the immediate future, it may be assumed that the total integrated RBE dose received by all radiation workers will be small in comparison with the integrated RBE dose of the whole population. Furthermore, persons outside of controlled areas, but exposed to radiation from a controlled area, constitute only a small portion of the whole population. Therefore, if this small portion is assumed to receive yearly an average per capita dose of 0.5 rem, the total dose to the whole population from man-made radiations is not likely to exceed 10 million rems per million of population up to age 30. (This assumes a dose of 4 million rems per million of population over this age period from background radiation.)

Dated: January 8, 1957

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[1] *The recommendations of the NCRP are regularly published in the NBS Handbook series, copies of which may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. The following handbooks containing NCRP recommendations are currently available at the indicated prices per copy: H42,* Safe Handling of Radioactive Isotopes, *20¢; H48,* Control and Removal of Radioactive Contamination in Laboratories, *15¢; H49,* Recommendations for Waste Disposal of Phosphorus-32 and Iodine-131 for Medical Users, *15¢; H51,* Radiological Monitoring Methods and Instruments, *20¢; H52,* Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water, *25¢; H53,* Recommendations for the Disposal of Carbon-14 Wastes, *15¢; H54,* Protection against Radiations from Radium, Cobalt-60, and Cesium-137 (*revision of H23*), *25¢; H55,* Protection against Betatron-Synchrotron Radiations up to 100 Million Electron Volts, *25¢; H56,* Safe Handling of Cadavers Containing Radioactive Isotopes, *15¢; H58,* Radioactive-Waste Disposal in the Ocean, *20¢; H59,* Permissible Dose from External Sources of Ionizing Radiation, *30¢; H60,* X-ray Protection (*revision of H41*), *20¢; H61,* Regulation of Radiation Exposure by Legislative Means, *25¢.*

[2] *See* Meetings on radiation units and protection, *NBS Tech. News Bul.* **40**, *102 (July 1956).*

Free Radicals Symposium

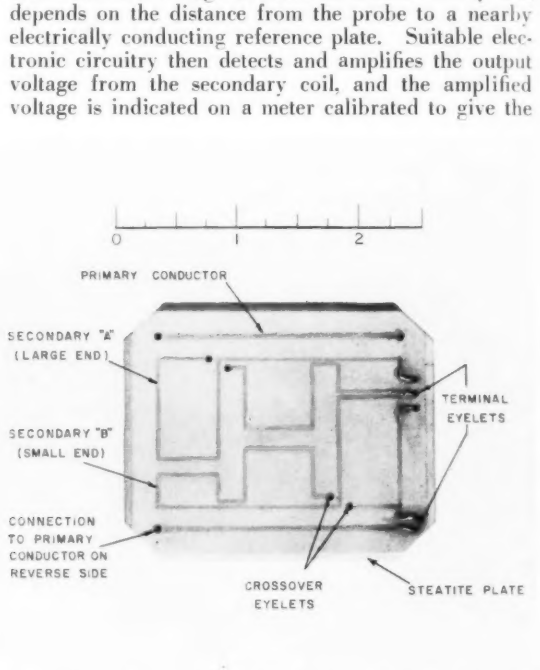
A THREE-DAY SYMPOSIUM on the Formation and Stabilization of Free Radicals will be held at the Bureau September 18–20, 1957. The meeting will be sponsored jointly by the Applied Physics Laboratory of the Johns Hopkins University, the Catholic University of America, and the National Bureau of Standards.

Recent advances in low-temperature physics, high polymer research, and other fields have stimulated much scientific interest in the isolation and study of free radicals. A number of industrial, Government, and university laboratories are now conducting free radical research programs which should yield results of broad significance in basic chemistry and physics. The conference is expected to provide a valuable medium for information exchange in this rapidly growing field.

Arrangements are being made by an executive committee composed of F. O. Rice of Catholic University, S. N. Foner of the Applied Physics Laboratory, Akrevy Pappas (Secretary) of NBS, and A. M. Bass (Chairman) of NBS. Further information on the program may be obtained from Dr. A. M. Bass, Free Radicals Research Section, National Bureau of Standards.

ROTOR POSITION INDICATOR
for studying steam turbines

AN ELECTRONIC INSTRUMENT that continuously measures the clearance between the rotating and stationary blades inside a steam turbine has been developed by the National Bureau of Standards. The detecting element of the system is a mutual-inductance micrometer [1] probe in printed circuit form on a ceramic base that resists high-temperature steam erosion inside the turbine. Designed for the Navy Bureau of Ships by M. L. Greenough and J. Johansen of the Bureau's electronic instrumentation laboratory with assistance of other sections of the Bureau, this rotor position indicator will aid in the study of steam turbines under actual operating conditions.

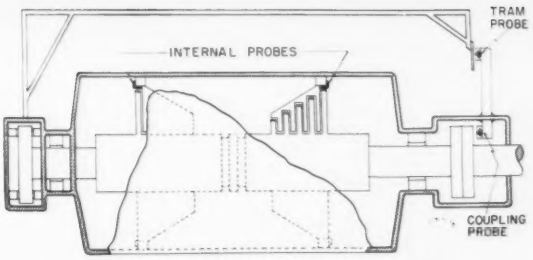


Left: **Electronic chassis for the rotor position indicator for continuously measuring the clearance between rotating and stationary blades inside a steam turbine. Transverse motion up to 0.4 in. can be measured; radial expansion of 0.2 in. produces no more error than 0.02 in. in measuring transverse motion.** ***Right:*** **Detecting probe for rotor position indicator is essentially a mutual-inductance micrometer probe in printed circuit form on a ceramic base. The printed pattern of conductors is glazed to protect the silver from steam erosion inside the turbine. To minimize crossover connections, conductors are printed on both sides of the plate and connections are made through small holes filled with conducting material.**

One of the problems in steam turbine operation is that of maintaining safe axial clearance between rotating and stationary blades. The rotor and stator blade assemblies are supported respectively by the massive rotor and the relatively thin outer casing. Thus, transient thermal conditions can cause large differential expansions, possibly resulting in interference between the blades. The NBS rotor position indicator permits accurate determination of blade clearance by measuring the axial distance from the shrouding around the rotor blade tips to the base of the outer stator blades. Because conditions at the blade tips are extremely severe—high velocity steam at 700° F—a temperature-resistant probe is essential.

A typical mutual inductance probe [2] contains two coplanar, coaxial coils wound on a dielectric core. An rf source that is regulated with respect to the product of the frequency and current energizes the primary coil. The a-c voltage induced in the secondary coil depends on the distance from the probe to a nearby electrically conducting reference plate. Suitable electronic circuitry then detects and amplifies the output voltage from the secondary coil, and the amplified voltage is indicated on a meter calibrated to give the probe-to-surface measurement in inches or centimeters. The instrument can detect very rapid displacement changes.

To measure the transverse motion of the shroud band, the energized primary winding induces voltages in two secondary coils that cover separate halves of the primary winding area. These half-windings are connected in series opposition so that there will be no voltage output when the band around the blades is centered over the probe. This band corresponds to the reference plate of the typical mutual inductance probe. Eddy



Cutaway drawing of steam turbine showing where probes are mounted inside the turbine. Tram probe is for checking accuracy of internal probes.

currents induced in the band as it approaches the coil assembly set up an opposing field that reduces the mutual inductance between windings. When the band is directly over the center of the probe, the inductance in each half-winding is reduced by an equal amount and no net output results. If the band moves transversely so that the half-windings are unequally covered, the inductance of one coil increases and the other decreases. As a result, there is a voltage output that is nearly a linear function of the transverse motion away from the center of the probe. However, a change in radial clearance (i. e., when the band moves toward or away from the probe) changes the sensitivity of the probe and introduces error in the measurement. To measure axial motion independently of radial shift, a voltage is generated in the probe that controls the amplitude of the exciting current. This voltage is proportional to the sensitivity for transverse motion, decreases as the radial clearance increases, and remains constant as the band moves transversely.

The rotor position indicator probe is about 3 in. long, 2½ in. wide, and ¾ in. thick. With respect to the turbine, its length is axial, its width tangential, and its depth radial. The coil configuration is printed on a steatite plate, ⅛ in. thick, mounted at the top surface of the probe housing. The printed pattern of conductors is glazed to protect the silver from erosion by steam. To minimize crossover connections, conductors are printed on the back as well as the front of the plate and connections are made through small holes filled with conducting material. The outgoing leads are brought up through tubes that have been fused into holes in the edge of the plate using a conducting joint compound. The tubes are compressed and spot-welded over the wires.

Under normal turbine operation the probes may last several hundred hours, but when the turbine is frequently subjected to severe transient conditions, such as sudden reversal of direction, the life of the probes may be as short as 30 hours. This, however, is adequate, as the probes are used only for relatively short test runs of the turbine. A few probe failures have occurred from cracking of the ceramic plate. This trouble has been successfully combatted by so designing its supporting frame that the plate is not subjected to distorting forces.

The accuracy of the rotor position indicator can be checked only by indirect methods. Rubbing pins worn away by the shroud band indicate clearances that agree with probe measurements, and independent probe measurements at various points also agree. Transverse motion up to 0.4 in. can be measured and a radial shift of 0.2 in. produces an error in transverse measurement of less than 0.02 in. Rivet heads and slots in the shroud band cause no appreciable error, but at low speeds the slots cause severe fluctuations in the output. This flicker disappears above a few hundred revolutions per minute; below that speed it can be reduced with suitable filters.

[1] Technical details of an electronic micrometer, *Electronics* **20,** *11* (*November 1947*).

[2] Electronic micrometer, *NBS Tech. News Bul.* **31,** *37* (*April 1947*); Micromanometer, *ibid.*, **34,** *137* (*October 1950*); Electronic stepmeter reveals mechanics of walking, *ibid.*, **35,** *50*, (*April 1951*); Oil film thickness indicator, *ibid.*, **35,** *120* (*August 1951*); Electronic sensing of mercury column height, *ibid.*, **36,** *26* (*February 1952*); Vibration pickup calibrator, *ibid.*, **37,** *181* (*December 1953*); A shaft displacement indicator, *ibid.*, **38,** *70* (*May 1954*); Design criteria for mutual-inductance transducers, *ibid.*, **39,** *36* (*March 1955*); An electronic position-tracking instrument, *ibid.*, **40,** *68* (*May 1956*).

New Weights and Measures Film

Testing Mass Standards by Substitution, a 22 min, 16-mm, color and sound film, has been produced by NBS at the request of the National Conference on Weights and Measures. The film, which is the second of a series,[1] presents recommended procedures for testing mass standards by substitution weighing.

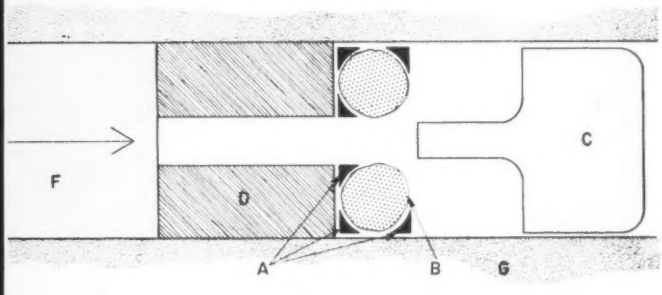
Though designed primarily as a training aid to weights and measures officials, the film may also be useful to science classes and laboratory personnel. It demonstrates a simple method for quickly determining with a high degree of precision the mass of an "unknown" standard by comparison with one of a known value. This is known as "error testing". Also demonstrated is the technique of "tolerance testing," a simpler procedure used when determining whether or not the error of a standard is within certain prescribed limits.

Convenient forms for recording and computing results in error testing and in tolerance testing are illustrated and explained. The several steps involved in each method are demonstrated by means of successive entries of data on the appropriate form. Live scenes are supplemented by animation. For information regarding the loan or sale of this film, write to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

[1] *A True Standard*, 12 min, 16-mm, color and sound, was produced in 1954.

Improved High-Pressure Packing

NBS SCIENTISTS have successfully used polytetrafluoroethylene impregnated with 5 percent by weight of molybdenum disulfide as a packing material in the high-pressure moving seal of differential-area pressure intensifiers.[1] The packing has served effectively at pressures approaching 200,000 pounds per square inch. The use of this packing material was developed in the course of the NBS program, sponsored in part by the Army Ordnance Corps, to extend the range of high-pressure standards and improve techniques of pressure measurement.[2]



The impregnated polytetrafluoroethylene (Teflon) packing [3] was used with a mushroom plug and extrusion ring assembly similar to that described by Bridgman.[4] The ram of the intensifier pushes against a cylindrical ring of hardened steel, into the hollow of which the stem of the mushroom plug fits. Held in a framework of copper beryllium extrusion rings, the packing is placed in the annular region between the hardened steel ring and the mushroom plug. In this position, the packing isolates the effectively zero pressure in the hollow of the steel ring from the high pressure at the annular surfaces where the packing touches the steel ring and the plug.

Intensifiers packed in this way were found to have from 10 to 15 percent less over-all friction than similar intensifiers packed with leather. Because other sources besides packing contribute to the over-all friction, improvement in packing friction is appreciable.

After more than 100 hours under load, with 18 pressure applications up to between 100,000 and 190,000 psi, one of the intensifiers was disassembled and examined. No signs of packing extrusion were found. In fact, the original tool marks were still visible on the surface of the plastic packing material that had been exposed to the rubbing action of the intensifier wall. The absence of extrusion is believed due either to the presence of the filler in the plastic or to the shape of the extrusion rings, or both.

Exploded cross-sectional diagram of the moving seal configuration in a high-pressure intensifier. This arrangement was used in studies of impregnated polytetrafluoroethylene as a packing material. A, copper beryllium extrusion rings; B, the impregnated plastic packing material; C, mushroom plug; D, hardened steel ring; E, high-pressure fluid; F, ram; G, intensifier wall.

Further studies on impregnated plastics are in progress. Also under investigation are the effects of changing size, angles, and materials used in extrusion rings.

[1] Impregnated Teflon as a packing material at 150,000 pounds per square inch, *by H. A. Bowman, J. L. Cross, D. P. Johnson, J. D. Hill, and J. S. Ives, Rev. Sci. Instr.* **27**, *550 (July 1956)*.

[2] High-pressure standards, *NBS Tech. News Bul.* **40**, *96 (July 1956)*.

[3] *The packing material was chosen after consultation with H. S. White, of the Bureau's rheology laboratory, who has used these materials in experiments on oil-free bearings.*

[4] The physics of high pressure, *by P. W. Bridgman, pp. 34, 39 (G. Bell and Sons. London, 1949)*; The design of high pressure plant and the properties of fluids at high pressure, *by D. M. Newitt, pp. 84, 86 (Oxford Univ. Press, 1940)*.

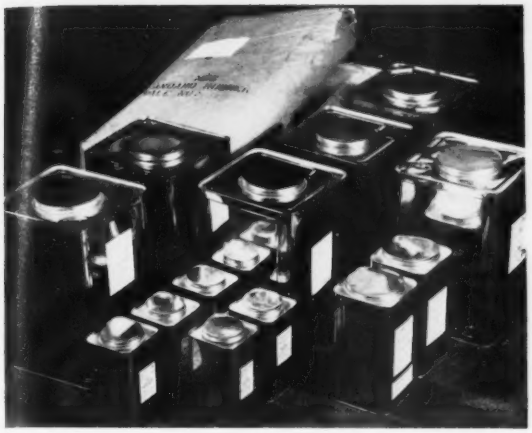
New Standard Samples for Rubber Compounding

THE BUREAU has added two synthetic rubbers to its list of standard samples for rubber compounding. They are styrene-butadiene rubbers types 1000 and 1500, the first rubbers issued as standard samples.

A total of 15 standard samples for rubber compounding (listed in table 1) are now available from the Bureau. This series was initiated in 1948 at the request of the Office of Rubber Reserve, Reconstruction Finance Corp. It consisted originally of seven compounding ingredients used in the quality control of synthetic rubber production. Later the American Society for Testing Materials Committee D–11 on Rubber and Rubberlike Materials requested the Bureau to prepare additional standard samples for use in testing and quality control of other raw materials. This committee also sponsored the establishment of one of the new standard samples, rubber type 1500.

The two synthetic rubber samples are copolymers of styrene and butadiene. Type 1000 is polymerized at a temperature of 50° C, whereas 1500 is polymerized at 6° C. These rubbers are used as reference standards in the formulations given in ASTM Designation D15 and in specifications for synthetic rubbers. Designated as Standard Samples 386 and 387, they are available in bales of about 34 kg (75 lb) priced at $23.00 for the type 1000 and $27.00 for the type 1500.

The preparation of the standard samples for rubber compounding has necessitated the development of special laboratory processing and testing equipment. Special mill rolls [1] were designed and constructed for maintaining uniform surface temperature during mixing of the rubber compound. The mold used for curing the rubber at NBS was machined directly into the hot plates of the vulcanizing press, and controls



Standard samples for rubber compounding now available from the Bureau. The two synthetic rubber samples (rear) are available in 34 kg (75 lb) bales, wrapped with polyethylene film and packaged in multiwall paper bags. The other samples are packaged in airtight metal containers.

were installed for keeping the temperature during vulcanization within 0.1° C. Improvements were also made in the Mooney viscometer [2] and a strain tester [3] was developed to attain the necessary test precision.

[1] Temperature control during mixing of rubber compounds, *F. L. Roth, G. E. Decker, and R. D. Stiehler, Rubber World* **132,** *482, (1955); for summary article see NBS Tech. News Bul.* **40,** *30 (Feb. 1956).*

[2] Factors affecting results obtained with the Mooney viscometer, *R. H. Taylor, India Rubber World* **112,** *584 (1945);* Influence of variations in rotors, dies, and rates of shear on Mooney viscosity, *G. E. Decker and F. L. Roth, India Rubber World* **128,** *339 (1953); note on* Adjustment of a Mooney viscometer die closure, *G. E. Decker, ASTM Bulletin No. 195 p. 51 (1954);* Temperature measurement in the Mooney viscometer, *G. E. Decker and R. D. Stiehler, ASTM Bulletin No. 195, p. 45 (1954).*

[3] Strain test for evaluation of rubber compounds, *F. L. Roth and R. D. Stiehler, J. Research NBS* **41,** *87 (1948);* Strain tester for rubber, *W. L. Holt, E. O. Knox, and F. L. Roth, J. Research NBS* **41,** *95 (1948).*

TABLE 1. *NBS standard samples for rubber compounding*

Number	Name	Approx. weight of sample in grams	Price per sample
370	Zinc oxide	2,000	$2.15
371	Sulfur	1,400	1.75
372	Stearic acid	600	1.90
373	Benzothiazyl disulfide	500	1.75
374	Tetramethylthiuram disulfide	500	3.50
375	Channel black	7,500	3.50
376	Light magnesia	450	2.40
377	Phenyl beta-naphthylamine	600	4.00
378	Oil furnace black	7,000	3.50
379	Conducting black	5,500	3.50
380	Calcium carbonate	6,000	2.50
381	Calcium silicate	4,000	2.50
382	Gas furnace black	7,500	3.50
386	Styrene-butadiene rubber, type 1500	34,000	27.00
[a] 387	Styrene-butadiene rubber, type 1000	34,000	23.00

[a] This sample is the remainder of reference rubber X-768 GR-S established in 1955 by the Federal Facilities Corp., Office of Synthetic Rubber.

STANDARD SAMPLES OF NICKEL OXIDE

TWO new standard samples of nickel oxide powder are now available from the Bureau. Although designed primarily as spectrographic standards, they also are useful as chemical standards. Analyzed and certified for nine minor and trace elements, the standards are intended for checking and calibrating spectrochemical and chemical methods employed in the analysis of nickel, particularly cathode-grade material.

Thermionic properties of nickel and nickel alloys used in the electronics industry depend largely on chemical composition. Accurate, reliable methods of analysis, together with standard samples, are thus needed to maintain the composition requirements.

The two nickel oxide standards were prepared in a cooperative program between the Bureau and a task group of Committee F–1 of the American Society for Testing Materials. They are designed primarily for application in the spectrographic analysis of cathode-grade nickel by Suggested Method E–2, SM 5–1 (*Methods for Emission Spectrochemical Analysis,* American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa., 1953).

The compositions of the nickel oxide standards given in table 1 are the averaged analytical results of 14 cooperating laboratories representing the Bureau and producers and consumers of cathode nickel. A provisional certificate of analysis accompanying each standard sample lists the analytical results of the cooperating laboratories, which are as follows:

Chemical:

National Bureau of Standards, Washington, D. C.
Western Electric Company, Hawthorne Works, Chicago, Ill.
Sylvania Electric Products, Inc., Towanda, Pa.
Sylvania Electric Products, Inc., Kew Gardens, N. Y.
United States Metals Refining Company, Carteret, N. J.
Bell Telephone Laboratories, Murray Hill, N. J.
Wilbur B. Driver Company, Newark, N. J.
Raytheon Manufacturing Company, Newton, Mass.
Driver-Harris Company, Harrison, N. J.

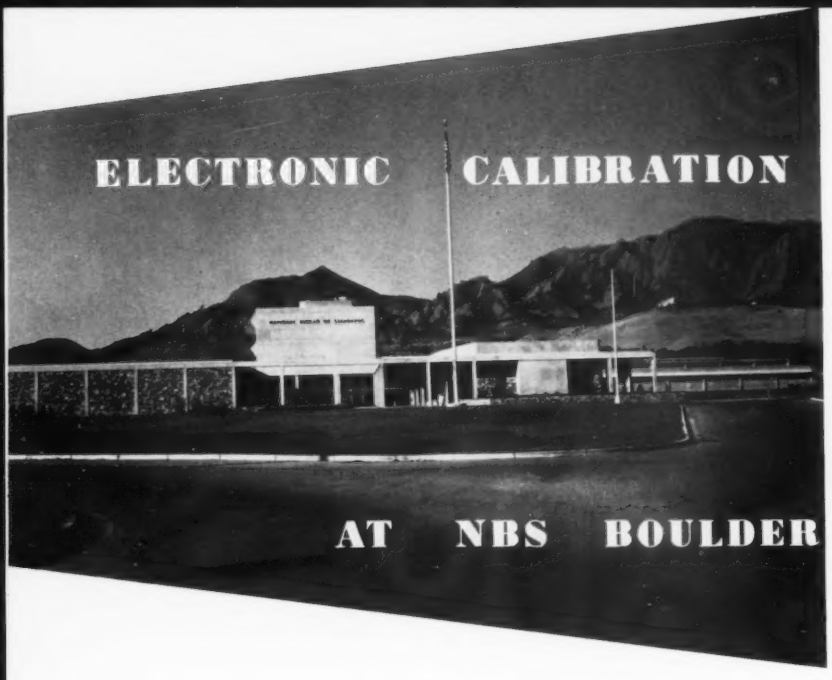
Spectrochemical:

National Bureau of Standards, Washington, D. C.
W. B. Coleman and Company, Philadelphia, Pa.
Bell Telephone Laboratories, Murray Hill, N. J.
Raytheon Manufacturing Company, Newton, Mass.
Westinghouse Electric Company, Elmira, N. Y.

The nickel oxide standards are packaged in bottles containing 25 grams and are available from the Standard Sample Clerk, National Bureau of Standards, Washington 25, D. C. The fee is $4.00 per sample.

TABLE 1. *Compositions of NBS spectrographic standards of nickel oxide*

NBS No.	Co	Cu	Fe	Mg	Mn	Si	Ti	Al	Cr
	%	%	%	%	%	%	%	%	%
671	0.31	0.20	0.39	0.030	0.13	0.047	0.024	0.009	0.025
672	.55	.018	.079	.020	.095	.11	.009	.004	.003



ELECTRONIC CALIBRATION CENTER AT NBS BOULDER LABORATORIES

CONSTRUCTION has begun on an Electronic Calibration Center to be established at the Boulder (Colo.) Laboratories of the National Bureau of Standards. Scheduled for completion in 1957 at a total cost of about $2,000,000, the new center will provide the Bureau with greatly expanded facilities for electrical and electronic calibration services at all frequencies now in general use.

The Calibration Center will occupy a 27,000 square foot wing in the Bureau's radio building at Boulder. This wing is now being constructed at a cost of about $750,000. Simultaneously, work is under way on the design and construction of over $1,000,000 worth of reference standards and specialized equipment for the Center.

The Calibration Center is being set up in response to the armed services' urgent and continually increasing need for accurately calibrated electronic equipment to be used in radar, aircraft control, and missile guidance. About half the cost of a modern fighter plane now goes into electronic devices for navigation, fire control, and other purposes. In order for this equipment to work together as a unit, each of the separate components must be specified, constructed, and evaluated according to accurately calibrated reference standards.

For example, in air-to-air refueling of Air Force planes, radar navigation equipment is used to rendezvous the tanker with the aircraft to be refueled. To assure contact between the two aircraft, their navigation equipments must be precisely calibrated in terms of a single frequency standard. This requires a total of 29 test instruments, each accurate to one-tenth of 1 percent. To calibrate the test instruments to this accuracy, 25 measurement standards, accurate to 0.01 percent, must be used. Such uniformity requires inspection and calibration of all secondary standards by a single agency in terms of a master set of standards.

The primary mission of the Calibration Center will be to calibrate interlaboratory secondary standards for such quantities as voltage, power, and impedance against master standards to be maintained at the Center. These interlaboratory standards, in turn, will be used to assure the accuracy of working standards in laboratories, on the production line, and in overhaul stations. This service is expected to be of great value not only to the armed services but also to the electronics and communications industries.

Initially, the Center will perform calibrations at particular fixed frequencies already in wide use ranging up to 40,000 Mc. However, its eventual aim will be to measure and standardize all usable electrical and radio quantities from direct current, or zero frequency, to at least 100,000 Mc. Work in the range from direct current up to 30 kc will be shared with the Bureau's Washington laboratories. At first the Federal Government is expected to be the largest user of the calibration service, but the Center's facilities will also be available to industry, universities, and scientific organizations.

The Calibration Center will have a staff of about 50, headed by Harvey W. Lance. It will function as a part of the Bureau's radio standards laboratory which has been charged for many years with the responsibility for basic research and development leading to new and improved radio standards, measurement techniques, and associated instrumentation for all radiofrequency and microwave electrical quantities. The radio standards laboratory is also responsible for supplying the national primary radio standard and the calibration services.

The quantity of these calibrations required today is so great that branching chains of measurement are necessary to extend the primary standards to the shop or field instruments, the end goal of the calibration process. The large number of links in each chain, through which the units of measurement must be transferred, requires the highest practicable accuracy at each step in order to assure adequate accuracy of the shop and field instruments. The new Calibration Center should provide an effective means of transmitting accurately the Nation's basic electrical standards at all frequencies to a wide variety of users.

The fundamental system of electrical measurement now employed in the United States uses absolute units, that is, units derived from the fundamental units of length, mass, and time—the meter, kilogram, and second. Basic to the absolute system of electrical units are the absolute ohm and the absolute ampere. The absolute ohm is derived from the absolute henry, based on an inductor of accurately known dimensions. The absolute ampere is established in terms of the magnetic force on an accurately dimensioned current-carrying coil, measured with a current balance.

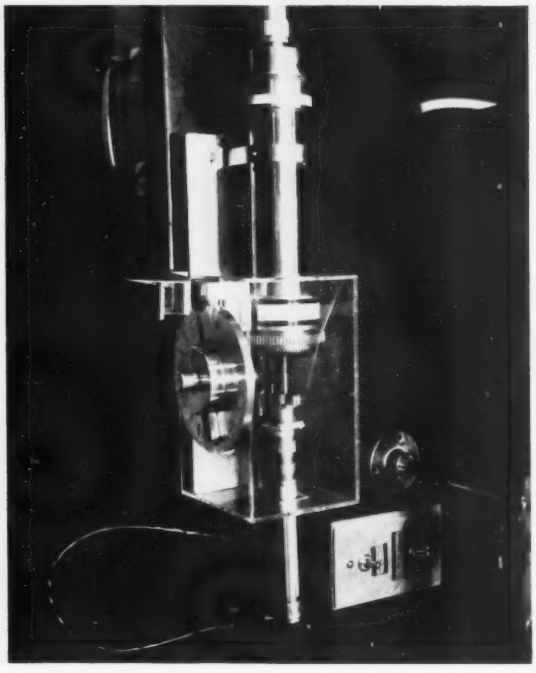
The accurate fundamental determinations of the absolute ohm and the absolute ampere made at the Washington laboratories are necessarily very difficult and time consuming. Hence, they are performed only every decade or so. Between such determinations, the values of the units are maintained at the Bureau by means of a group of standard resistors carefully calibrated in terms of the absolute ohm, and a group of standard cells, calibrated in terms of the absolute ampere and the absolute ohm. Other units, such as the watt, the kilowatt hour, and the joule, are obtained by combining these units and by appropriately extending the scale of measurement to other ranges.

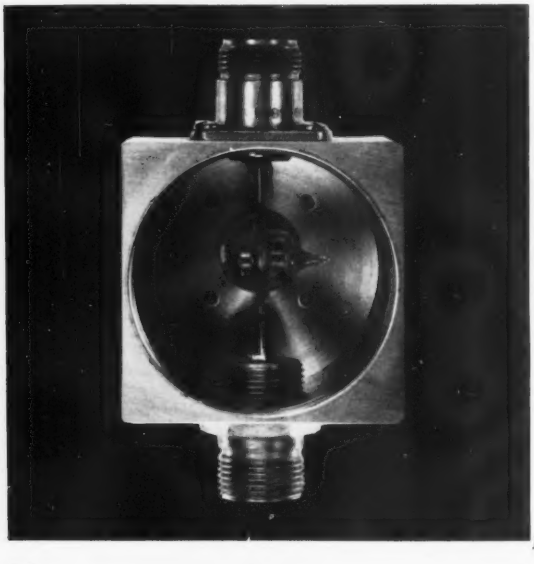
Various techniques are used to extend the units to the higher frequencies. At power frequencies, for example, the transfer is carried out by means of specially constructed electrodynamic voltmeters and wattmeters. In the microwave region absolute power measurements are made by directly comparing the heating effects of microwave and of d-c power.

The Calibration Center will maintain reference standards derived from the absolute ohm and volt. Those standards most urgently needed for the initial period of operation are now under construction. However, new standards will undoubtedly be required in the future to replace reference standards made obsolete by technological advances and to extend the capabilities of the Center as new calibration requirements arise. Thus, in addition to its calibration activities, the Center will conduct a long-range program for the continued development of reference standards especially adapted to its use.

Services offered by the Calibration Center will cover three broad frequency ranges: (1) low-frequency (zero frequency through about 30 kc), (2) high-frequency (30 kc through about 300 Mc), and (3) microwave (above 300 Mc).

Partially constructed wing that will house the new Electronic Calibration Center. White area on aerial photograph shows location of the new wing. Shown checking the construction plans are, left to right, W. D. George, in charge of the NBS Radio Standards Laboratory; Wilbert F. Snyder, Assistant Head of the Calibration Center; and Harvey Lance, who is in charge of the Center.





Above: **Waveguide-below-cutoff piston attenuator used in the IF substitution method of microwave attenuator calibration. Designed especially for the NBS Electronic Calibration Center, this attenuator utilizes a motor drive for rapid setting to any attenuation value.** ***Below:*** **Radiofrequency micropotentiometers will be incorporated into a special console to calibrate standard voltage generators at voltage levels of 1 to 100,000 μv and at all frequencies up to 1,000 Mc.**

Low-Frequency Standards

For many years calibrations in the direct-current and low-frequency range have been performed by the Bureau's Electricity and Electronics Division in Washington. A group from that Division is now designing and procuring suitable reference standards for use in the Calibration Center. This group will transfer to the Boulder Laboratories to operate there the calibration facilities in the low-frequency range. Calibration services in this frequency range will continue to be available in Washington also.

In the lower-frequency range the work of the Calibration Center will include the calibration of standard cells, resistors, inductors, capacitors, volt boxes, potentiometers, bridges, a-c and d-c indicating instruments (voltmeters, ammeters, and wattmeters), instrument transformers, and current shunts. Other calibration activities will be added as the need arises. The reference standards for these measurements consist of highly accurate bridges, potentiometers, stable sources of current and voltage, and the like. Commercial equipment is used whenever it is available, but a number of specially designed instruments and consoles are required to provide the necessary accuracy and ease of measurement.

High-Frequency Standards

In the high-frequency range the Calibration Center will make measurements of voltage, current, impedance, power, attenuation, and field strength. For all of these measurements, stable sources of high-frequency power, voltage, or current are required, as well as stable detectors or indicators.

In order to achieve the desired frequency stability, crystal-controlled power sources and receivers are being used whenever possible. In addition to frequency stability, the sources must have very nearly constant power output. Power stabilization circuitry is being developed that will prevent power output variations greater than 0.1 percent over periods up to one-half hour. Exciters operating at the 5- or 10-watt level are adequate in some cases. In others, amplifiers operating at the 100-watt level will be used. For the initial stages of Calibration Center operation, provision is being made for the measurement of power levels at radiofrequencies only to 100 watts.

For most quantities, measurements are to be made at the fixed frequencies of 30, 100, and 300 kc, and 1, 3, 10, 30, 100, and 300 Mc, with the frequencies of 5, 200, and 400 Mc (and probably 600 and 800 Mc) also provided for voltage measurements. In addition to the fixed frequency standards, provision is being made for continuous frequency coverage when necessary, but these standards will be less stable and hence their accuracy will not be as great.

High-frequency voltage measurements will be simplified by use of the recently developed attenuator-thermoelement (A-T) voltmeters [1] as reference standards. A-T voltmeters have been incorporated into special consoles designed for accurate and rapid meas-

urements over the voltage range 0.2 to 300 v. Micropotentiometers will be used as reference standards for the lower voltages required in signal generator calibration.

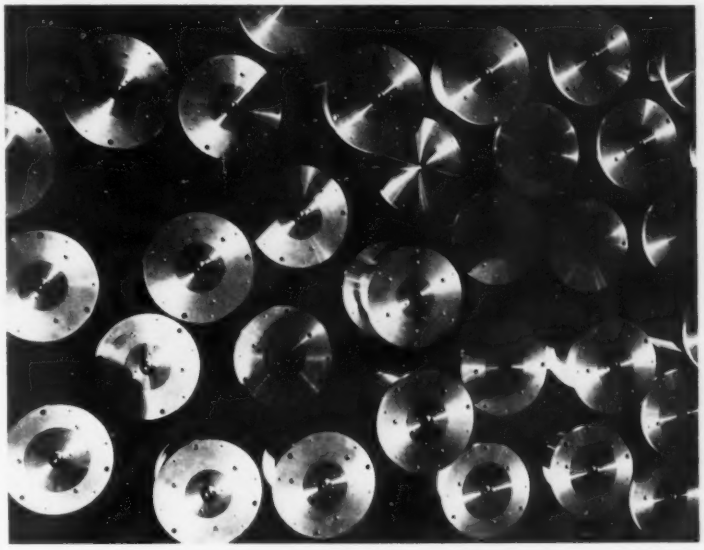
High-frequency current is measured by means of thermoelements calibrated against electrodynamometer-type standards. However, for the initial phase of Calibration Center operation, this facility will not be provided.

For high-frequency impedance measurements, a set of 18 fixed-frequency bridges is being designed. These bridges will be used in connection with a set of newly developed coaxial impedance standards. For continuous frequency coverage, the best available commercial bridges will be used, with frequent calibration against the special impedance standards.

Microwave Standards

In the microwave region, preparations are being made for measurement of impedance, power, attenuation, and frequency. Except at the lower end of the range, measurements of voltage, current, and field strength are not considered very important at present. These measurements will probably be covered later by extensions of the high-frequency techniques now in use.

As in the high-frequency range, calibrations will be made primarily at certain fixed frequencies. Although crystal control is less practicable in this region, other stabilization techniques are available which permit a high order of frequency stability. When necessary, power stabilization will also be used in the microwave power sources.



Some of the several hundred impedance standards that have been developed at the Boulder Laboratories of the National Bureau of Standards to calibrate resistors, capacitors, inductors, and complex impedance at radiofrequencies. These standards employ a standardized termination that achieves maximum accuracy and allows rapid calibration.

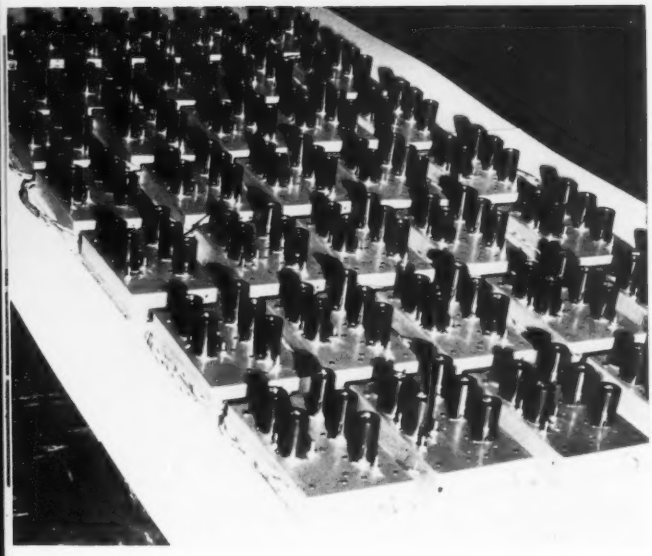
For power measurements in the high-frequency range, a bolometer bridge, a conduction calorimeter, and a liquid-flow calorimeter will serve as reference standards for the power range from 1 mw to 100 w. A special power comparator is being developed that will permit accurate comparison of power dissipated simultaneously in the reference standard and in a power meter under calibration.

High-frequency attenuation measurements will be made by a null-detection, direct-substitution method, in which the reference standard is either a waveguide-below-cutoff piston attenuator or, at the lower end of the frequency range, a four-drum decade attenuator.

The calibration of a field strength meter will include calibration of the attenuator and the amplifier linearity by application of the attenuator and power measurement techniques described above. Antenna coefficients will be determined with standard loops below 30 Mc, or standard dipoles above 30 Mc. These will be calibrated by standard antenna and field methods.

In the microwave region measurements must be made with both coaxial and waveguide equipment. Whenever possible, the fixed frequencies, 400, 1000, 2,000, 4,000, and 8,000 Mc, will be used for coaxial measurements. The highest frequency at which accurate coaxial measurements should be attempted is around 8,000 Mc. However, in rectangular waveguides provision is now being made for measurements over the frequency range 2,600 to 40,000 Mc. To cover this range requires eight different waveguide sizes. Above 40,000 Mc, three addtional sizes of waveguide will extend the frequency range at a later date to 90,000 Mc.

Because of the lack of suitable klystrons or other oscillator tubes, it is difficult to specify a uniform set of frequencies for microwave measurements. In general, however, plans call for three fixed frequencies for each waveguide size, one near the middle and one near each end of the waveguide frequency range. Substantially continuous frequency coverage will also be available when required.



Fifty special low-noise crystal-controlled converters have been recently developed to extend the frequency range of available receivers upwards from 30 to 500 Mc. They are to be used in the Bureau's new Electronic Calibration Center as sensitive selective voltmeters to monitor accurately levels down to less than 1 μv at spot frequencies.

In the initial phase of Calibration Center operation, provision is being made only for low-level microwave power measurements. This includes power levels up to 10 or 100 mw. Calibrations of waveguide equipment will use as reference standards bolometer mounts and bolometer-mount-directional coupler combinations that have been calibrated by calorimetric methods. Coaxial bolometer mounts will be calibrated by the impedance method of measuring mount efficiency.

Microwave attenuation measurements will employ the IF substitution method or the direct substitution method, whichever is more applicable. With the IF substitution method, the maximum attenuation that can be measured with high accuracy is generally limited to about 50 db by mixer linearity considerations. When higher values of attenuation are required, the direct substitution method may be used. In this method the standard attenuator must be calibrated for each microwave frequency, but the procedure can be used to measure attenuation up to 75 db with an accuracy nearly equal to that of the other method.

Microwave frequency measurements will utilize a frequency multiplier chain having crystal-controlled output at selected frequencies up to 24,000 Mc. By combining the marker frequencies in a crystal harmonic generator, any required frequency up to about 100,000 Mc can be obtained. The highly stable crystal-controlled oscillators will be set with reference to frequency standards based on unchanging properties of the atom.

Facilities

The Calibration Center will contain 16 laboratory rooms as well as additional space for offices, instrument storage and repair, and shipping and receiving. Twelve of the rooms will be completely shielded to minimize interference with sensitive measuring equipment. There will also be a radio "darkroom" having walls lined with absorbent material. This will make possible various radio measurements indoors; for example, the calibration of field strength meters under approximately free-space conditions. Air-conditioning equipment will maintain constant temperature and relative humidity while mechanical filters and electrostatic precipitators will be used to eliminate dust from the conditioned atmosphere. Line-voltage regulation will assure stability of reference standards and accuracy in the calibration process.

[1] Stable radiofrequency voltmeters, *NBS Tech. News Bul.* **40**, 29 (*Feb. 1956*).

APPLICATIONS OF OPTICAL TECHNIQUES AT MILLIMETER WAVELENGTHS

AT the Boulder (Colo.) Laboratories of the Bureau work is being directed towards ascertaining the magnitude of the diffraction correction to be applied to wavelengths observed with microwave interferometers operating in the near-field or Fresnel region as well as in the distant field. This is a most important objective for the application and use of such interferometers, because in the near-field region stray radiation effects are much less. Also energy loss due to diffraction in the interferometer is greatly reduced compared with that lost when operating in the distant field of the radiator where, as a limit, the inverse square law applies.

In general, the transverse dimensions of waveguide transmission systems compare with the wavelength. Consequently, as generators of wavelengths extending into the millimeter and submillimeter region become available, the attenuation in the required waveguide system increases and construction and measurement techniques become more difficult to apply. As an alternative to waveguide systems it is natural to consider the application of optical methods of transmission and measurement for these ultrashort wavelengths. In this application, mirrors and lenses are used whose dimensions can be many wavelengths, limited only by practical considerations. Also, the problems of ob-

taining an efficient transmission system and of making accurate measurements with optical methods become less severe as the wavelength decreases.

So far the main work in this field has been directed towards the application of optical interferometers to the microwave region, and microwave models of both the Michelson [1] and Fabry-Perot interferometers [2] have been made, together with the microwave analogue of the optical spectrometer.[3] These have given good results in wavelength and dielectric constant measurements in the microwave region. The apertures that can be used in such microwave interferometers are, however, very much smaller in terms of the wavelength than those normally used in optical instruments. Thus, a consideration of the diffraction that inevitably occurs is most important in their design and use. Such a diffraction correction has been applied by Froome [4] to obtain the first definitive value for the velocity of electromagnetic waves with a microwave Michelson interferometer operating in the distant field of an electromagnetic horn radiator.

Initially the Boulder Laboratories' investigation will be concerned with the microwave analogue of the Michelson interferometer at a wavelength of 6 mm. Electromagnetic horns with apertures of 30 cm and 60 cm square will be used. Each horn is fitted with a dielectric lens to produce a plane phase front across the aperture. Lens surfaces are matched to free space to avoid reflections from them. A large mirror moving in a substantial slide will produce the interference fringes, and the wavelength will be determined by counting the number of fringes in an accurately known displacement of the mirror. These measurements will be made at various distances from the radiating horn. Coupled with the theoretical work on diffraction, these results should enable the magnitude of the correction to be assessed with confidence.

Plans have also been made to investigate the microwave model of the Fabry-Perot interferometer in a similar way. Here very sharp fringes, due to multiple reflections between two highly reflecting surfaces, lead to greater precision in the setting of the interferometer. It is also suspected that because of the multiple reflections and consequent high degree of selectivity the magnitude of the diffraction correction to the observed wave length may be less in this interferometer. A solution [2] to the problem of obtaining the high reflectivity is to use a number of quarter-wave plates of fused quartz spaced a quarter wavelength apart in air. By this means reflectivities approaching that of silver can be obtained without serious absorption of the microwave radiation. Like its optical counterpart, this interferometer is certainly the more precise one regarding resolution. Also, it is of great intrinsic interest in application to the microwave region.

As far as standards are concerned, the microwave interferometer's main application is in the field of metrology. This is due to the very high degree of monochromatic radiation that can be achieved at microwave frequencies. Frequency stabilities of 1 part in 10^8 are obtained with relative ease by frequency multiplication from a quartz crystal, or by frequency stabilization with a cavity resonator. By careful design and operation of these methods, it is possible to attain still higher degrees of frequency stabilization. Also, use can be made of atomic and molecular beam resonances, such as the cesium atomic beam resonator, with which frequency stabilities around 1 part in 10^{10} have already been achieved.

Parabolic radiator used in initial studies of the microwave Michelson interferometer. The wavelength used is 6 mm, and adjustments in azimuth and elevation are provided as well as in height and distance from the small radiating horn shown. The radiation travels to a mirror, where it is reflected and returned to the parabola. By comparing the returned signal from the mirror with a reference signal, the "fringes" may be seen as the mirror is moved, and the apparent wavelength in free space may be determined.

Compared to the spectral line widths at optical wavelengths, which imply frequency stabilities of about 1 part in 10^6, the microwave frequency stabilities that can be achieved are phenomenal and lead to excellent visibility of the fringes over lengths of tens of meters, instead of about 10 cm as in the optical case. The relative setting accuracy of the microwave interferometers at these large path lengths compares with that obtained in optical interferometers at the shorter lengths. Setting accuracies of $\pm 3 \times 10^{-4}$ cm have already been attained in the Michelson interferometer at path lengths of 20 m; and by the use of the Fabry-Perot interferometer with its sharper fringes, this setting accuracy can be further improved.

Electromagnetic horn radiator designed for use in improved Michelson interferometer and also in proposed Fabry-Perot interferometer. The aperture is 30 cm square and will be fitted with a matched dielectric lens to give optimum radiation pattern. Wavelength to be used is 6 mm. Diagram of wavelength Fabry-Perot interferometer. The radiated waves travel to the composite reflector system, where multiple reflections take place. Very sharp fringes are obtained in the receiving horn when the reflectors are positioned so that the multiple reflections add in phase.

The Bureau hopes to exploit fully the factors limiting the sensitivity of the microwave interferometer, which are susceptible to a high degree of control and measurement. These are the power of the source and its spectral purity, and the use of the superheterodyne receiver, which provides linear detection down almost to the thermal limit of detectability.

Microwave interferometers are not only important to precise length determinations but they also provide a method, whose potentialities have not yet been fully exploited, for the precise determination of the velocity of electromagnetic waves.

The main problem in these applications is that of ascertaining the accuracy with which the diffraction correction can be applied to the positions on the microwave interferometer as determined by the fringes. This more pronounced effect of diffraction arises because of the limited aperture size practicable at the wavelengths presently available. Practical dimensions at present are around 100 wavelengths. In optical interferometers the dimensions of the components would be at least 10^4 wavelengths. The effects of diffraction are thus more marked in microwave interferometers, and may be assessed by considering the angular spectrum of radiation that constitutes the polar diagram of the aperture distribution. The field at any point in front of the aperture is due to a superposition of the plane waves in this angular spectrum instead of to a single plane wave. This leads to a departure from an ideal plane wave in the interferometer, and to phase deviations that depend on the path length. Calculations indicate that for an aperture of 60 cm and a wavelength of 6 mm, these effects can give rise to an error of about 1 part in 10^5 in a length determination with the Michelson interferometer operating in the near-field region. Consequently, for the measurement of length and velocity of electromagnetic waves to within 1 part in 10^7, it is necessary to establish the magnitude of the diffraction correction to within 1 percent.

It is also necessary to determine the refractive index of air at these wavelengths, and this may be done with a microwave refractometer to a precision comparable with that obtained in the optical range, corresponding to an accuracy of about 1 part in 10^7.

As microwave power at shorter wavelengths in the millimeter-wave region becomes available, the effects of diffraction on the accuracy of the interferometers is reduced. For example, at a wavelength of 1 mm and an aperture 60 cm square, the calculations indicate that the diffraction correction is less than 1 part in 10^6, showing the improvement in accuracy at these shorter wavelengths.

Finally, there are other fields of investigation as regards the application of optical techniques to millimeter wavelengths. These include the use of the microwave analogue of the optical spectrometer, studies of total reflection with application to a prism attenuator, and also the search for other microwave analogues of optical phenomena.

---

[1] The Michelson interferometer at millimeter wavelengths, *by W. Culshaw, Proc. Phys. Soc.* [B] **63,** *939 (1950).*

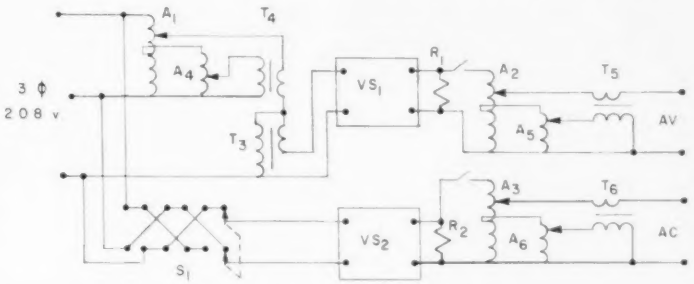
[2] The Fabry-Perot interferometer at millimeter wavelengths, *by W. Culshaw, Proc. Phys. Soc.* [B] **66,** *597 (1953).*

[3] A spectrometer at millimeter wavelengths, *by W. Culshaw, J. Inst. Electr. Engrs. (London)* **100,** *part IIA, No. 35 (1953).*

[4] Determination of the velocity of short electromagnetic waves by interferometry, *by K. D. Froome, Proc. Phys. Soc.* [A] **213,** *123 (1952).*

POWER SUPPLIES FOR INSTRUMENT CALIBRATION

THE BUREAU has constructed for its own use, convenient, inexpensive power supplies for calibrating a-c electrical instruments and meters over wide ranges of voltage, current, and power. Devised by F. L. Hermach and E. S. Williams of the Bureau's electrical instruments laboratory, these power supplies incorporate commercially available 60-cycle electronic voltage stabilizers that operate from an ordinary 3-phase line. Although the circuit arrangements are not new, their combination with commercial voltage stabilizers results in power supplies that should prove useful to other standardizing laboratories.



Circuit diagram of the NBS power supplies. Auto transformers, A_2, A_3, A_5, and A_6, and the 120/5 v transformers, T_5 and T_6, are used to control the output voltages of the two voltage stabilizers, VS_1 and VS_2. Switch S_1 shifts the phase angle between the two channels in 60° steps; auto transformers, A_1 and A_4, and 120/5 v transformer, T_4, provide 0–60° and 0–2° phase shifts respectively, for coarse and fine control.

For instrument testing, the most important requirement upon the power supply is that instrument pointer fluctuations be negligible while a measurement is being made. The standardizing of a-c ammeters and voltmeters is greatly facilitated by a power supply whose output is exceptionally free of fluctuations. Moreover, the output should have good waveform and be adjustable in fine and coarse increments over wide ranges of current and voltage. If wattmeters and phase-angle or power-factor meters are also to be tested, the supply should have two similar outputs of the same frequency, adjustable in phase so that "phantom loading" may be used. In the past, sine-wave motor-generator sets, both troublesome and expensive, have been used as instrument calibrating sources. They are now largely supplanted at NBS by power supplies using commercial stabilizers connected to simulate the desired test conditions.

The power supplies use two a-c voltage stabilizers fed from a 3-phase line through phase shifters, to produce two single-phase voltages which are independently adjustable in magnitude and in phase. Each supplies a multirange impedance-matching transformer, one to give an output, "AV", suitable for tests of voltmeters to 800 v, and the other an output "AC", for tests of ammeters to 100 amps.

For tests of wattmeters, watthour meters, and power-factor or phase-angle meters, the voltage circuits of the standard and test instruments are supplied by connection to AV and the current elements in series are supplied by connection to AC. The phase angle and the voltage magnitudes are then adjusted to obtain the desired test values. In this well-known phantom-loading method the sources are required to supply only the losses in the instruments, and there is no need to correct readings for these losses.

To be suitable for instrument testing, such power supplies must meet certain quantitative requirements. These have been evaluated, and can be simply determined with the indicating instruments usually available in most standardizing laboratories. The voltage stabilizers should have stabilization ratios of 20 or more, time constants of recovery from input voltage changes of not more than about 0.04 sec, and output-voltage phase-shifts of not more than about 4 min of angle for 1-percent changes in input voltage; they should not produce stray fields in excess of 0.05 gauss in locations where instruments are tested. Moderate waveform distortion is easily tolerated if only rms instruments are tested, but the form factor and crest factor must be known to a few tenths of a percent if rectifier instruments and the usual electronic voltmeters are to be tested with an rms standard.

For further technical details, see Power supplies for 60-cycle tests of electrical instruments and meters, *by F. L. Hermach, Proc. ISA, Vol. 11, 1956, paper 56-21-3.*

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Technical News Bulletin, Volume **41**, No. 1, January 1957. 10 cents. Annual subscription $1.00.

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TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

February 1957 **Vol. 41, No. 2**

Issued Monthly

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price, domestic $1.00 a year; 35 cents additional for foreign mailing; single copy, 10 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (March 29, 1956).

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RP2730. The Kösters interferometer. J. B. Saunders.

RP2731. Spectral absorbance of some aqueous solutions in the range 10° to 40° C. Elizabeth E. Sager and Fleur C. Byers.

RP2732. Radiant-heat transfer between nongray parallel plates. Stanley Goodman.

RP2733. Wavelengths from iron-halide lamps. Robert W. Stanley and William F. Meggers.

RP2734. Resistance of flow in Teflon and brass tubes. Marion R. Brockman.

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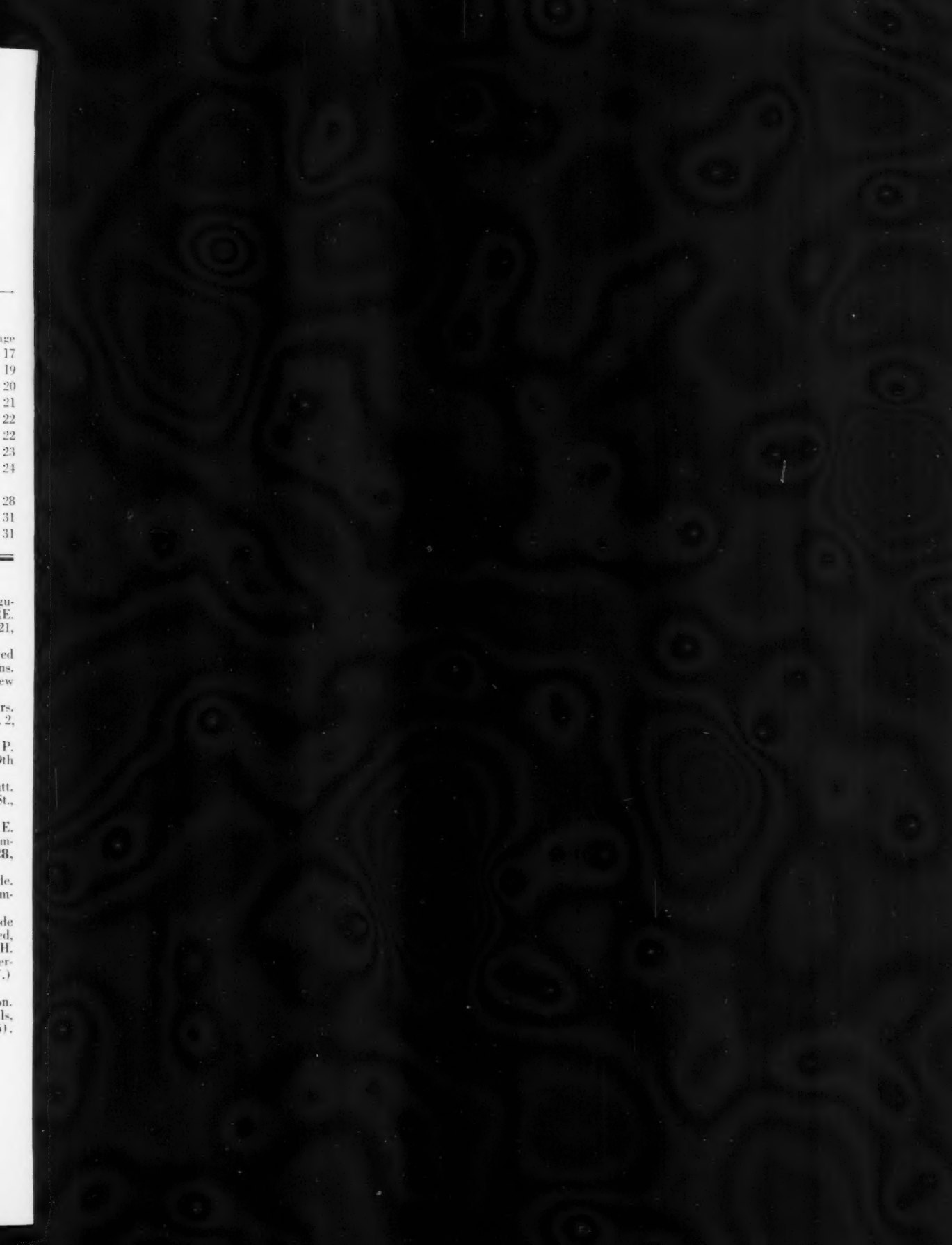
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